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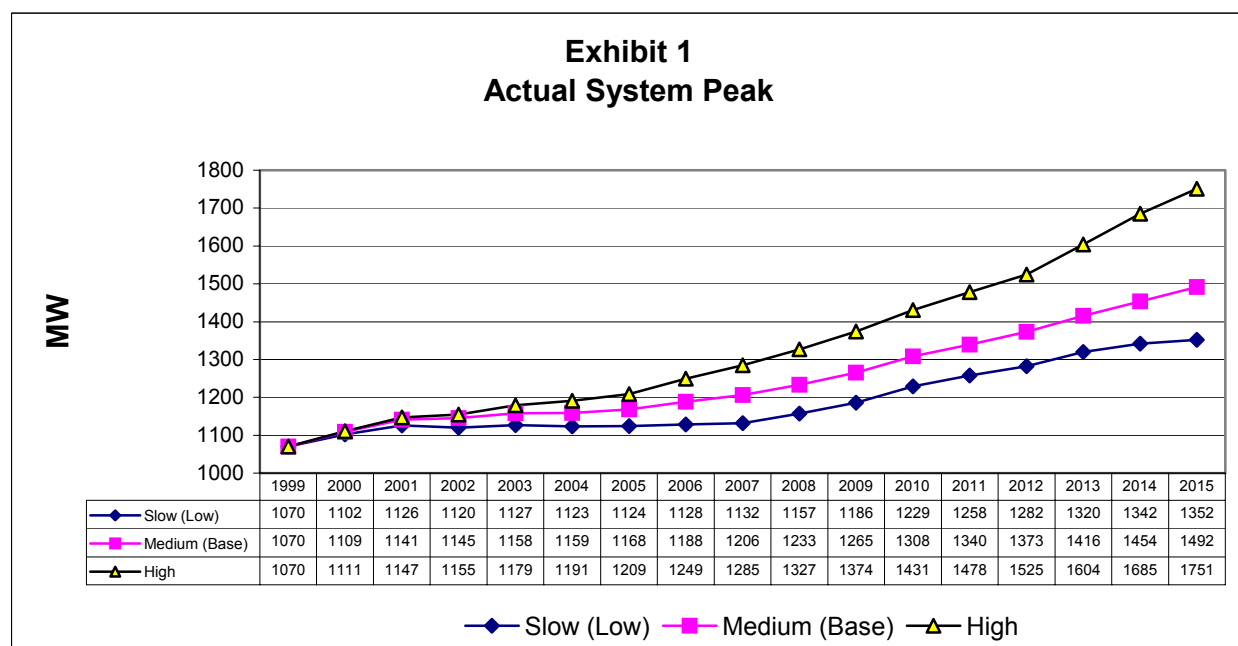
## CHAPTER 11 CONCLUSIONS AND RECOMMENDATIONS

### 11.1 Electricity Demand

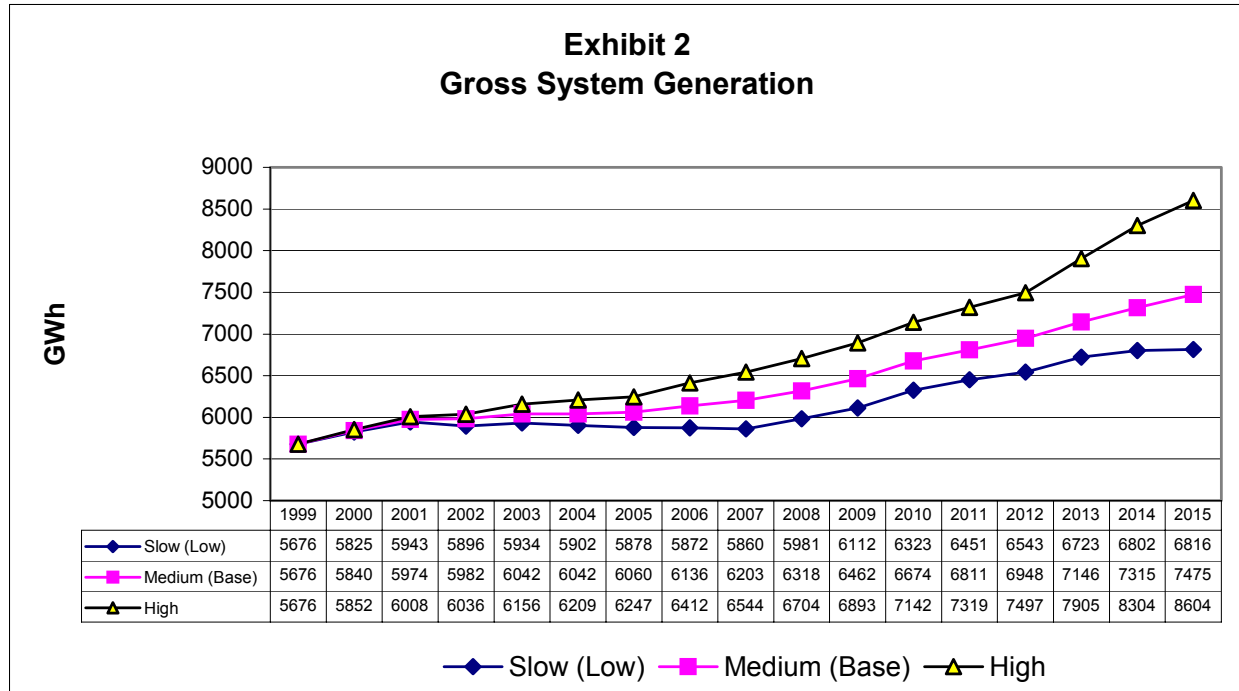
The Armenian economy is in a state of recovery. Total Produced GDP is expected to grow at an average rate of 4% in the 1999-2015 in Base Case. Total Produced GDP average 1999-2015 growth for high and low cases is 5% and 3% accordingly.

As a result, the actual system peak in Armenia is expected to grow from about 1070 MW in 1999 to 1,492 MW in 2015 for base case.

Peak growth will be gradual at first but will pick up momentum as the economy gains strength. The actual system peak forecasts are shown on Exhibit 1.



The gross system generation forecasts are presented on Exhibit 2. Gross system generation is expected to grow from about 5,676 GWh in 1999 to 7,475 GWh in 2015 for base case.



## 11.2 Existing Generation

### *Hydro Generation*

Hydroelectric generation will continue to be one of the most important sources of electricity for Armenia for the foreseeable future. Geographic and weather features provide reliable conditions for hydro generation, and the extensive investment made during the Soviet era in the country's hydro resources provides a good basis for rehabilitating existing plants. The major conclusions are:

- Sevan-Hrazdan HPP Cascade requires a capital investment of about \$32 million for normal operation during 2000-2020. All rehabilitation work should be carried out by 2005. The rehabilitation effort should not increase cascade's installed capacity or planned energy generation level, since water limitation (due to Lake Sevan water level increase and irrigation needs) will remain.
- Vorotan Cascade requires a capital investment of about \$40 million for rehabilitation by 2005. Although, the available capacity will be increased by 116 MW at the cascade, energy generation will actually decrease. This is due to the assumption that Vorotan-Arpa Water Tunnel will be completed by the end of 2004 that will divert significant amount of water (equivalent of about 240-260 GWh/yr.) to Lake Sevan from Vorotan Cascade.

- Existing small HPPs are subject to privatization (or already in private ownership) and all capital investment requirements are expected to be covered by potential buyers or current owners.

### ***Thermal Generation***

Thermal power will continue to play a major role in supplying Armenia's electric energy. Thermal power is primarily needed to provide base load energy during the fall and winter low water seasons. However, as the availability of new hydroelectric station sites that can be developed is exhausted, thermal power will increase its share of total generation. At that time, gas-fired combined cycle units will become the dominant technology for new plants.

### **Condensing Units**

- Yerevan TPP Units 6 and 7 are fairly old, uneconomical, and expensive to maintain. Analysis performed shows that these units can be shut-down to minimize overall system cost. Decommissioning can be performed as early as 2001. The exception is the case, when new gas-fired capacity additions will not be able to enjoy the benefit of the IPP fuel arrangement. In this case, the units should be preserved in the system until physical obsolescence, i.e., in 2010.
- Hrazdan TPP Block Units 1-4 should be maintained during 2000-2020. Although the units are not fully dispatched in economic scenarios due to relatively high cost, capacity factors for these units gradually increase, reaching 60-70% by the end of study. Units 1 (and possibly 2 and 3 depending on steam demand) can be refurbished to extract low-pressure steam for district heating. This project will allow Hrazdan TPP to close-down the Combined Heat and Power (CHP) part of the plant. *A detailed feasibility study should be conducted for this project that should involve the original turbine manufacturer's advice before any work commences on the refurbishment of Units 1-3 and the decommissioning of the existing CHP part.* Current cost estimate for this project is around \$2 million.
- In order to successfully operate Hrazdan TPP Block Units 1-4 for next 20 years, three (3) cooling towers should be rehabilitated. No other significant expenditures (in addition to regular and major overhaul maintenance) are proposed for the plant. Capital investment for these 3 cooling towers totals about \$20 million and assumes gradual rehabilitation during 2001-2004.
- The uncompleted Hrazdan Unit 5 should be treated as new project and is discussed later in this Chapter.

### **CHP Units**

- Current steam demand at Yerevan TPP cannot substantiate the maintenance of 4 operating CHP units. All of the demand for steam can be satisfied with one unit in operation. The future increase of steam demand is questionable. Ministry of Industry (MoI) (through

Ministry of Energy) have provided their steam demand for 2004-2008. The increase of steam consumption almost quadruples from the current level by 2008 in this forecast. There is no substantiation for such a steep increase and the forecast was modified in line with the base economic projections.

- Three cases were reviewed with regard to steam demand in Yerevan region: (a) High Steam Demand (corrected MoI forecast), (b) Current Steam Demand, and (c) No steam Demand (i.e., steam is generated by industrial enterprises and DH boilers). Cases (b) and (c) result in no new CHP capacity additions to the system. In case (b), the steam demand is satisfied with two (2) existing CHP units at Yerevan TPP. In case (a), there is merit in introducing a new 82 MW CC CHP. The capital requirements for this unit were assumed to be \$56.2 million. Sensitivities show that the increase of capital up to \$60-62 million will still make this project the least-cost steam generation alternative with high steam demand. The fuel price also affects the decision on this unit: The current natural gas price makes the unit installation unattractive, however, situation reverses assuming an IPP fuel price and high steam demand.
- Since the steam situation is not clear, *a detailed study should be conducted of any potential industrial customers in Yerevan Region to determine the most probable steam demand level for the next 10 years*. No active steps should be taken toward the contract and/or construction of this project before the proposed study is conducted.
- Hrazdan CHP plant is the subject for potential decommissioning. The decommissioning should be proposed only after the project to convert Block Units 1-3 to low-pressure steam is completed with positive results.

### ***Nuclear Generation***

The fate of the ANPP at Medzamor should be resolved in the near future. The analysis performed clearly shows the following:

- Armenian energy system will enjoy significant total system savings with the deferral of the ANPP decommissioning. Total accumulated systems savings (in new capital deferral and fuel savings) is estimated to be about \$82 million when ANPP is decommissioned in 2010 instead of 2005, and about \$251 million when ANPP is decommissioned in 2015 instead of 2005.
- Nuclear safety issues are outside of scope of this study.
- Decommissioning cost for Unit 2 is assumed to be about \$225 million (Y2000 \$US) and is not expected to vary depending on decommissioning year. This figure is based on the typical decommissioning practice in the US and *should be updated upon the completion of a detailed cost estimate for ANPP decommissioning currently being performed by MoE under EU aegis*.

### 11.3 New Capacity Additions

#### *Hydro Generation*

In addition to the existing hydropower plants, 3 major projects have been proposed and a number of small hydro projects were studied as new generating plants. However, none of them were found to be economically attractive for implementation during the planning period in the economic evaluations. This was due to a few key factors. Most of the proposed plants have rather low yearly energy production capability and high capital investment needs. However the issue of fuel security in the region may allow some hydro capacity in the future. Specific recommendations are as follows:

- Before any activities take place in regard to Megri HPP project, a water sharing agreement should be in force between Armenia, Iran, Turkey, and Azerbaijan. All of these countries may impact the availability of water with their irrigation, household, and electric needs.
- In order to accommodate the fuel security issues, Megri, Shnokh, and Loriberd plants were installed in system (in Strategic Base Case) the same year when a new 400 MW CC is installed in Base Economic Case. The capital investment requirement for all three plants is estimated to be about \$378 million.
- Total system cost difference between economic and strategic base cases is about \$363 million. In other words, this cost has to be substantiated by external (i.e., political) factors in order to implement any hydro development.
- New hydro power has long lead time for design, engineering, construction, and commissioning. No new hydro generation options can be realistically developed before 2007.

#### *Thermal Generation*

- Hrazdan Unit 5 completion and re-powering to combined cycle is considered to be the least-cost option for thermal generation. Total capital investment requirement for this project is estimated to be \$125 million. In all economic cases, Hrazdan 5 is installed in 2004 based on the effort to minimize total system cost and energy requirements. *Since Hrazdan 5 is a non-completed gas-fired supercritical unit, a detailed feasibility study is required before any actual completion and/or conversion project is started to verify estimates to complete it as well as its economic attractiveness.*
- A new standard 400 MW CC is the second least-cost alternative for the system. The total capital investment for this project is about \$235 million. The per unit cost can be decreased based on the number of units required. The first addition of this unit in Base Economic Case is in 2011.
- A new Circulated Fluidized Bed (CFB) unit is the only strategic generation alternative reviewed in this plan. The introduction of this unit is based on the assumption of local coal availability. Although this alternative is fairly expensive, it can be considered “least-cost” among all strategic alternatives. The only promising coal field in Armenia at this time is the Ijevan deposit. *Further exploration of this deposit is recommended before any activities on the new CFB unit are*

*commenced.* The more expensive mix of Georgian and Armenian coals does not diminish the selection of this option.

### ***Nuclear Generation***

- Two nuclear technologies were considered for Armenia. US or European reactor technology was dismissed in the screening analysis based on the high life-cycle cost. The future of a new Russian VVER-640 reactor project is uncertain, so that the reactor may not be available in the near to medium term.
- Current capital investment estimates for new VVER-640 plant are nearly \$1 billion. The option is included in this study and total system costs with a new NPP are calculated. The difference between economic and strategic cases with a nuclear option is anywhere in the range of \$1-1.3 billion, which makes the substantiation of new NPP very difficult, even based on fuel security issues.

## **11.4 Investment Plan**

### ***Economic (Least-Cost)***

The investment requirements for major capital improvements for the Armenian electric generation power system will total approximately \$275 Million USD for the period from 2001 to 2005 (excluding ANPP retirement), and \$235 Million USD from 2006 through 2020 for base forecast economic case. The specific projects and their costs are shown in the table below.

| Type           | Station                | Cost<br>Mil. USD (Y2000) |
|----------------|------------------------|--------------------------|
| <b>Hydro</b>   | Vorotan Cascade        | 31.7                     |
|                | Sevan-Hrazdan Cascade  | 39.8                     |
| <b>Thermal</b> | Hrazdan TPP Rehab      | 20.0                     |
|                | Yerevan TPP Rehab      | 0.8                      |
|                | Hrazdan CHP Conversion | 2.0                      |
|                | Hrazdan Unit 5         | 125.0                    |
|                | New 400 MW CC          | 232.3                    |
|                | New 82 MW CC CHP       | 56.2                     |
| <b>Nuclear</b> | ANPP Decommissioning   | 225.0                    |
| <b>TOTAL</b>   |                        | <b>732.9</b>             |

***Strategic***

The investment requirements for major capital improvements for the Armenian electric generation power system will total approximately \$275 Million USD for the period from 2001 to 2005 (excluding ANPP retirement), and \$440 Million USD from 2006 through 2020 for base forecast economic case. The specific projects and their costs are shown in the table below.

| Type           | Station                | Cost<br>Mil. USD (Y2000) |
|----------------|------------------------|--------------------------|
| <b>Hydro</b>   | Vorotan Cascade        | 31.7                     |
|                | Sevan-Hrazdan Cascade  | 39.8                     |
|                | New Megri              | 160.0                    |
|                | New Shnokh             | 121.0                    |
|                | New Loriberd           | 97.0                     |
| <b>Thermal</b> | Hrazdan TPP Rehab      | 20.0                     |
|                | Yerevan TPP Rehab      | 0.8                      |
|                | Hrazdan CHP Conversion | 2.0                      |
|                | Hrazdan Unit 5         | 125.0                    |
|                | New 82 MW CC CHP       | 56.2                     |
|                | New CFB                | 59.0                     |
| <b>Nuclear</b> | ANPP Decommissioning   | 225.0                    |
| <b>TOTAL</b>   |                        | <b>937.6</b>             |